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(54) Brewing beer

(57) When brewing yeast is treated with oxygen, the rate at which it takes up oxygen increases until a maximum take-up rate is reached. The yeast is then fully oxygenated. In a method of fermenting wort for the production of beer, wort that contains little or no oxygen is pitched with fully oxygenated yeast to enable fermentation to occur. The process leads to improved consistency as the outcome of the fermentation can be accurately predicted in advance. In one method, an aqueous suspension of yeast from a tank (4) is circulated by means of a pump (8) through ducting (7) containing an oxygenation cell (9). The oxygen content of the suspension is monitored by an oxygen electrode (14). A control unit (12) increases the rate at which oxygen is supplied to the oxygenation cell in such a manner as to maintain the concentration of oxygen in the suspension constant. When a steady state is reached the fully oxygenated yeast is transferred to a storage tank (17). When the yeast is to be transferred to a fermentation vessel (19) the concentration of fully-oxygenated yeast in a sample of given volume is measured by determining the rate of oxygen take-up.

Figure 4

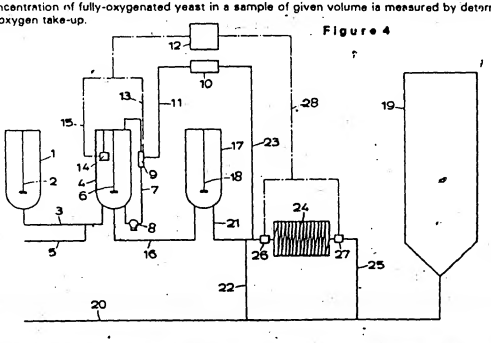

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Figure 1

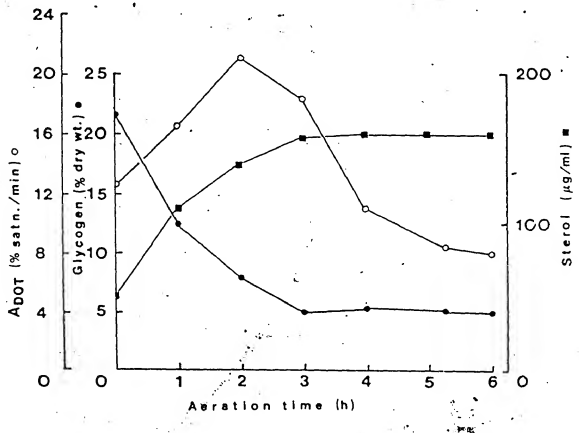
24
20
16
12
8
4
0
A_{DOT} (% satn./min) ○
25
20
15
10
5
0
Glycogen (% dry wt.) ●
200
100
0
Sterol (μg/ml) ■
0
1
2
3
4
5
6
Aeration time (h)

Figure 2

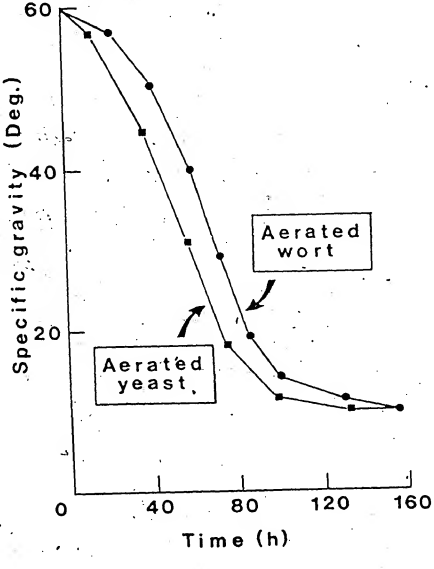
60
40
20
0
40
80
120
160
Specific gravity (Deg.)
Time (h)
Aerated wort
Aerated yeast

Figure 3

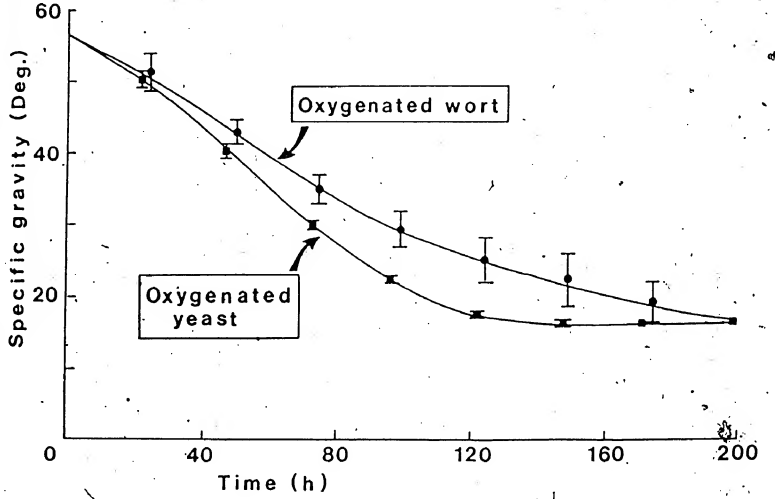

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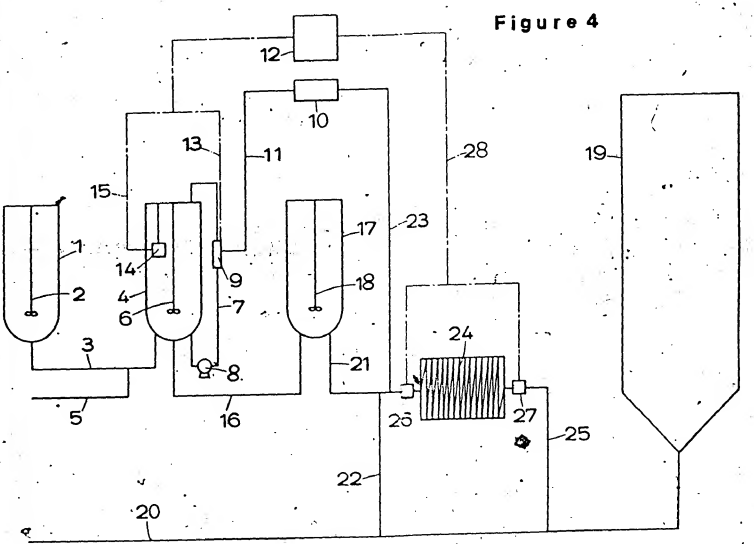
Figure 4



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SPECIFICATION

Brewing be r

This invention relates t the br wing f beer.

It is desirable to carry out fermentations for the production of beer in such a menner thet the outcome can be, as far as possible, predicted in advance and achieved with great consistency.

An aim of the present invention is to provide a novel modification to normal fermentation practice thet assists in this being achieved.

Hitherto it has been the usual practice in the brewing of beer to pitch with yeast derived from a previous fermentation. Such yeast has been deprived of oxygen and is generally referred to as aneerobic yeast.

In order that the satisfactory fermentation of wort should occur, it is necessary for aneerobic pitching yeast to synthesize essential lipid components, principally sterols and unsaturated fatty acids. These processes are dependent upon the provision of molecular oxygen and the presence within the yeast cells of sufficient reserves of the storage carbohydrate, glycogen (Quain, D. E. & Tubb, R. S. Master Brewers Association of the Americas, Technical Quarterly, 1984, *19*, 29–33). Consequently, it has the usual practice in the brewing of beer to prepare wort in such a manner thet it contains a relatively high proportion of dissolved oxygen and to store pitching yeast under conditions that minimize glycogen dissimilation.

However, although it had been thought that the use of oxygenated wort was beneficial it has now been discovered that the precise quantity of oxygen administered is vital in determining the efficiency of the fermentation process. Thus, sub-optimal oxygen concentrations in wort will result in slow fermentations. Conversely, supra-optimal oxygen concentrations in wort will result in excessive yeast growth and a reduced ethanol yield.

It has now been discovered that if pitching yeast suspended in liquor is exposed to oxygen, prior to pitching, this results in the syntheses of sufficient sterol and unsaturated fatty acids such that no further provision of oxygen to the wort is required in order to achieve a satisfactory fermentation. Furthermore, the fermentation may be controlled simply by the careful control of pitching rate. Such fermentations are faster and less subject to variations than are those performed in the usual menner.

It is therefore intended to employ wort that contains no oxygen or at least a proportion of oxygen significantly less than that employed in a conventional fermentation process, such wort being hereinafter referred to as oxygen-free wort, and to pitch it with yeast that has been subjected to oxygenation, such yeast being hereinafter referred to as oxygeneted yeast.

From a first aspect the present invention consists in a method of fermenting wort for the production of beer, in which brewers' yeast is treated with oxygen until the rate at which it takes up oxygen reaches or at least closely approaches a maximum in the preveiling conditions, the yeast then being fully oxygenated, and oxygen-free wort is pitched with a predetermined quantity of that already fully-oxygenated yeast to enable fermentation to occur.

The yeast may be treated with gaseous oxygen or with air or with other oxygen-conteining gas to effect oxygenation.

In a preferred method of oxygenation, oxygen (alone or as part of a gaseous mixture) is introduced into an aqueous suspension of yeast, the oxygen content of the suspension is monitored, and the rate at which oxygen is introduced is increased in such a manner as to maintain the concentration of oxygen in the suspension substantially constant, oxygenation continuing at least until such time as there is no longer eny need to increase the rate of introduction of oxygen to maintein the same concentration of oxygen in the suspension.

Thus, from a second aspect the present invention consists in a method of oxygenating brewers' yeast in which an aqueous suspension of brewers' yeast is oxygenated at a rate which is progressively increased in such a manner that the concentretion of oxygen in the suspension remains substantially constant. Oxygenation is preferably continued only until no further increase in the rate of oxygenetion is required to maintein the concentration of oxygen substentially constant.

Preferably oxygenation is effected by causing the suspension to circulate around a circuit conteining a tank or like container of relatively lerge volume and a cell of relatively small volume, oxygen being introduced into the suspension as it passes through the cell. The oxygen content of the suspension is prefarably monitored in the tank or like container.

From a third aspect the present invention consists in apperatus for carrying out a method in accordance with the second aspect of the present invention, comprising a tank or like conteiner for a suspension of brewers' yeast, means for oxygenating thet yeast, and means for monitoring the oxygen content of the suspension and controlling the rate of oxygenation in such a manner that the oxygen content of the suspension remains substantially constant.

The aqueous suspension of fully-oxygeneted yeast may be stored, without the addition of further oxygen, before being added to the wort. Storege preferebly takes place at a reduced

temperature.

The concentretion of fully-oxygenated yeast in en aqueous suspension used for pitching wort is preferably determined before the yeast is introduced into the wort in order to enable an appropriate volume of the suspension to be used. This determination is preferably effected by causing a sample of the suspension to pess, et e predetermined rete, elong a peth, introducing oxygen int the sample et a first location in the path end, by measuring the oxygen content at spaced locations in the path, determining the rate at which oxygen is taken up per unit volume of suspension, and, from a knowledge of the rate at which oxygen is taken up per unit weight of fully-oxygenated yeast, determining the concentration of fully-oxygenated yeast in that sample.

The invention will now be more particularly described with reference to the accompanying drawings, in which:—

Figure 1 is a graph illustrating a progressive increase in the rate at which oxygen is taken up by a sample of brewers' yeast.

Figure 2 and 3 are graphs illustrating methods of fermentation employing the present invention, and

Figure 4 is a diagrammetic illustretion of one type of apparatus embodying the present invention end for use in carrying out a method of the present invention.

In one experiment a 200g (wet weight) semple of en ale yeast derived from a previous brewery fermentetion was suspended in 2 l distilled water in a stirred glass vessel. Air wes then delivered into the suspension by means of a sterile filter and glass sinter at a rate of 1 l/min for a period of 6 h. During the time the temperature was maintained at 20°C. At intervals the air supply was discontinued and the rate at which dissolved oxygen was consumed by the yeast (ΔDOT) measured by means of a polarographic dissolved oxygen meter connected to a chart recorder. After measurement of oxygen upteke rates, samples of yeast were removed eseptically for analysis of glycogon and sterol, as described elsewhere (C.A. Boulton & D.E. Quain, Proceedings European Brewing Convention Congress, Madrid, 1987).

The results are shown graphically in Fig. 1 and reveal that with the commencement of aeration the observed ΔDOT increased to reach a maximum after two to three hours after which time it declined. During the first three hours of aeration there was a decline in the yeast intracellular concentration of glycogen and a concomitent increase in the levels of yeast sterol, such that constant values of each were observed at a time substantially coincident with the maximum, ΔDOT. The quantities of glycogen dissimileted end sterol synthesized were of the same order as those that may be measured during the aerobic phase of fermentations employing aneerobic yeast and aerated or oxygenated wort (Quain, D.E. and Tubb, R.S. MBAA Technical Quarterly 19, 29–33, 1982).

In another experiment a sample of an ale yeast derived from a previous brewery fermentation was aerated using a method and the apparatus of the kind described above. When the maximum ΔDOT was observed, yeast was removed and pitched into a stirred laboratory fermenter containing 5 l of anaerobic ale wort of specific gravity 1.060 to give a final yeast concentration of 3.75g/l—wet weight. The fermentation was maintained at 18°C and its progress monitored by removing samples for measurement of specific gravity. The resultant attenuation profile is shown in Fig. 2 together with that obteined using unaerated yeast and another sample of the same wort but which had been saturated with air at 18°C prior to pitching.

Using a method similar to that of the first experiment described above, but using oxygen in place of air, five samples of lager yeast derived from different brewery fermentations were treated until the maximum ΔDOT values were observed. Aliquots of the oxygenated yeast were pitched at a rate of 3.75 g/l—into stirred laboratory fermenters containing 1.5 l anaerobic semi-defined wort of specific gravity 1.060 (Quain, D.E. and Boulton, C.A. Proceeding European Brewery Convention Congress, Madrid, 1987). For the purposes of comparison aliquots of each yeast sample, untreated with oxygen, were pitched as described into similar wort saturated with oxygen at 11°C. Fermentations were maintained at 11°C and monitored by the removal of samples for specific gravity measurement. The mean attenuation profiles of each set of fermentations is shown in Fig. 4, the degree of variability being shown by the error bars.

Referring now to the apparatus illustrated in Fig. 4, this shows a yeast collection vessel 1, containing a stirrer 2, connected by way of a duct 3 to an oxygenation tank 4. A duct 5, leading from a source of water or other aqueous liquid (not shown) is connected to the duct 3. The tank 4 contains a stirrer 6. Ducting 7 leads from the tank 4 to a circulating pump 8 and thence by way of an oxygenation cell 9 back to the tank 4. The oxygenation cell 9 may contain a stainless steel tube or "candle" with perforations through which air or gaseous oxygen is caused to pass into the aqueous suspension of yeast that flows over the tube.

Air or gaseous oxygen can be introduced into the cell 9 from a source 10 by way of a duct 11. The rate of introduction of the gas into the cell is determined by the setting of a gas valve (not shown) which is controlled electrically by a control unit 12, through the intermediary of wiring 13. The unit 12 can receive signals from an oxygen electrode 14 mounted in the tank 4 by way of wiring 15.

Ducting 16 leads from the tenk 4 to a storage tank 17, which contains a stirrer 18.

The epparatus elso includes a fermentetion vessel 19 which can receive oxygen-free w rt through a wort main 20. A duct 21 leeds from the storage tank, and e duct 22 leads fr m the duct 21 to the wort main 20.

The duct 21 extends pest a junction with the duct 22, and at a location downstream f that junction is connected to a gas duct 23 connected to the source 10 f eir r oxygen. Bey nd its connection to the gas duct 23, the duct 21 is c nnected to the inlet of an attemperated coil 24, of which the outlet is connected to e duct 25 leading from the coil to the wort mein 20. At the inlet end of the coil 24 there is an oxygen electrode 26, and at the outlet end of the coil there is an oxygen electrode 27. Those electrodes 26 and 27 ere connected by wiring 28 to the control unit 12.

The apparatus operates in the following menner. Yeast, some of which may come from a previous fermentation, is held in the yeast collection vessel 1 in the form of en aqueous suspension. The suspension is mainteined at a relatively low temperature, for exemple at 4°C. Suspension from the vessel 1 is intermittently passed through the duct 3 to the oxygenation tenk 4. At the seme time, weter or other aqueous liquid is introduced through the duct 5 to dilute the suspension. In the tenk 4 the suspension is stirred by stirrer 6 end is mainteined et e temperature e little ebove embient temperature, for exemple et 20°C. Suspension is continuously withdrawn from the tank 4 through the ducting 7, by meens of the circuleting pump 8, and passed through the oxygenetion cell 9 before being returned to the tank. The suspension is thus continuously circulated through a circuit as referred to above. In its passege through the cell 9, the suspension hes oxygen applied to it. In the cell the suspension mey be broken up into e sprey so es to increase its surface area, whereby the yeast is brought more closely into contact with the oxygen. The oxygen is supplied to the cell 9 through the duct 11 from the source 10 and may be in the form of pure gaseous oxygen or in the form of eir.

As described above, it is a characteristic of brewers' yeast that, when oxygen is epplied to it, it takes up oxygen at a rate that increases with time until a steady state is reached at which the rate of teke up of oxygen is et a maximum. The apparatus illustrated operates in such e menner thet the oxygen content of the suspension in the tank 4 remains substantially constant during oxygenation. To this end, readings of the oxygen content of the suspension in the tank, taken by the oxygen electrode 14 are supplied to the control unit 12, and, in response, the unit 12 controls the gas valve in the cell 9. In order to achieve the desired result, the gas velve is progressively opened during oxygenation as the rate of take up of oxygen increeses.

When e steady state has been reached, requiring no further increese in the rate of supply of oxygen, the suspension of fully-oxygeneted yeast from the tenk 4 is transferred to the storage tank 17 by way of the duct 21. In the tank 17 the suspension is mainteined at a reduced temperature, for exemple at 4°C. It is stirred by the stirrer 18. No oxygen is introduced into the tank 17, but once the yeast hes been fully oxygenated, it remains in that state for a reletively long period.

Fully-oxygenated yeast from the storage tank 17 is used for pitching wort in the fermentation vessel 19. In order to ensure that the yeast is introduced into the wort at the correct concentration, the concentration of yeast in the suspension is determined immediately before the wort is pitched. To this end, a sample consisting of a relatively small volume of suspension, is caused to flow at a predetermined rate through the duct 21, through the coil 24, where it is maintained at a predetermined temperature, and thence through the duct 25 to the wort main. As the sample of suspension passes along the duct 21 towards the coil, oxygen from the source 10 is introduced into it by way of the gas duct 23. After leaving the suspension enters the coil 24, the oxygen content of the suspension is measured by the oxygen electrode 26. As the suspension leaves the coil, the oxygen content is measured by the oxygen electrode 27. As the length of the period of time taken for any part of the suspension to trevel from electrode 26 to electrode 27 is known, the rate at which oxygen is teken up by a given volume of suspension can be calculeted. This calculation is effected by the control unit 12. As the rate of oxygen take-up by a given weight of fully-oxygeneted yeast is e known constant, it is then possible to calculate the concentration of fully-oxygenated yeast in the suspension. This again is effected by the control unit 12. As the concentretion of fully-oxygenated yeast in the suspension is now known, it is possible to use that knowledge to calculate the volume of suspension that is needed to introduce a required weight of yeast into a predetermined volume of wort. When wort is introduced into the fermentetion vessel 19 through the wort main 20, the required volume of suspension is introduced into it by wey of the ducts 21 end 22. Allowance may be made for the relatively small sample quantity previously fed to the main through the duct 25.

Fermentation is carried out in a conventional manner, and the fermented product treated in a usual way to produce beer. Use of the present invention enables a high degree of consistency to be achieved between fermentations, such that beer of consistent quality can be produced.

CLAIMS

1. A method of fermenting wort f r the production of beer, in which brewers' yeast is treated with oxygen until the rate at which it takes up oxygen reaches or at least closely approaches a maximum in the prevailing conditions, the yeast then being fully oxygenated, and oxygen-free wort is pitched with a predetermined quantity of that already fully-oxygeneted yeast to enable fermentation to occur.

2. A method according to claim 1 in which oxygen (alone or as part of a gaseous mixture) is introduced into an aqueous suspension of yeast, the oxygen content of the suspension is monitored, and the rate at which oxygen is introduced is increased in such a manner as to maintain the concentration of oxygen in the suspension substantially constant, oxygenation continuing at least until such time as there is no longer any need to increase the rate of introduction of oxygen to maintain the same concentration of oxygen in the suspension.

3. A method according to either of claims 1 and 2 in which the wort is pitched with fully-oxygenated yeast in the form of an aqueous suspension, and the concentration of yeast in the suspension in determined before the yeast is introduced into the wort in order to enable an appropriate volume of the suspension to be used, that determination being effected by causing a sample of the suspension to pass, at a predetermined rate, along a path, introducing oxygen into the sample at a first location in the path and, by measuring the oxygen content at spaced locations in the path, determining the rate at which oxygen is taken up per unit volume of suspension, and, from a knowledge of the rate at which oxygen is taken up per unit weight of fully-oxygenated yeast, determining the concentration of fully-oxygenated yeast in that sample.

4. A method of oxygenating brewers' yeast in which an aqueous suspension of brewers' yeast is oxygenated at a rate which is progressively increased in such a manner that the concentration of oxygen in the suspension remains substantially constant.

5. A method according to claim 4 in which oxygenation is continued only until no further increase in the rate of oxygenation is required to maintain the concentration of oxygen substantially constant.

6. A method according to either of claims 4 and 5 in which oxygenation is effected by causing the suspension to circulate around a circuit containing a tank or like container of relatively large volume and a cell of relatively small volume, oxygen being introduced into the suspension as it passes through the cell.

7. A method according to claim 6 in which the oxygen content of the suspension is monitored in the tank or like container.

8. Apparatus for carrying out a method in accordance with any one of claims 4 to 7 comprising a tank or like container for a suspension of brewers' yeast, means for oxygenating that yeast and means for monitoring the content of the suspension and controlling the rate of oxygenation in such a manner that the oxygen content of the suspension remains substantially constant.

9. Apparatus according to claim 8 and substantially as hereinbefore described with reference to Fig. 4 of the accompanying drawings.

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1. A method of fermenting wort for the production of beer, in which brewers' yeast is treated with oxygen until the rate at which it takes up oxygen reaches or at least closely approaches a maximum in the prevailing conditions, the yeast then being fully oxygenated, and oxygen-free wort is pitched with a predetermined quantity of that already fully-oxygenated yeast to enable fermentation to occur.

2. A method according to claim 1 in which oxygen (alone or as part of a gaseous mixture) is introduced into an aqueous suspension of yeast, the oxygen content of the suspension is monitored, and the rate at which oxygen is introduced is increased in such a manner as to maintain the concentration of oxygen in the suspension substantially constant, oxygenation continuing at least until such time as there is no longer any need to increase the rate of introduction of oxygen to maintain the same concentration of oxygen in the suspension.

3. A method according to either of claims 1 and 2 in which the wort is pitched with fully-oxygeneted yeast in the form of an aqueous suspension, and the concentration of yeast in the suspension in determined before the yeast is introduced into the wort in order to enable an appropriate volume of the suspension to be used, that determination being effected by causing a sample of the suspension to pass, at a predetermined rate, along a path, introducing oxygen into the sample at a first location in the path and, by measuring the oxygen content at spaced locations in the path, determining the rate at which oxygen is taken up per unit volume of suspension, and, from a knowledge of the rate at which oxygen is taken up per unit weight of fully-oxygenated yeast, determining the concentration of fully-oxygenated yeast in that semple.

4. A method of oxygenating brewers' yeast in which an aqueous suspension of brewers' yeast is oxygenated at a rate which is progressively increased in such a manner that the concentration of oxygen in the suspension remains substantially constant.

5. A method according to claim 4 in which oxygenation is continued only until no further increase in the rate of oxygenation is required to maintain the concentration of oxygen substantially constant.

6. A method according to either of claims 4 and 5 in which oxygenation is effected by causing the suspension to circulate around a circuit containing a tank or like container of relatively large volume and a cell of relatively small volume, oxygen being introduced into the suspension as it passes through the cell.

7. A method according to claim 6 in which the oxygen content of the suspension is monitored in the tank or like container.

8. Apparatus for carrying out a method in accordance with any one of claims 4 to 7 comprising a tank or like container for a suspension of brewers' yeast, means for oxygenating that yeast and means for monitoring the content of the suspension and controlling the rate of oxygenation in such a manner that the oxygen content of the suspension remains substantially constant.

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